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Photoluminescence enhancement in nano-textured fluorescent SiC passivated by atomic layer deposited Al_2O_3 films

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Nano-textured SiC surface attracts intensive attention in fluorescent SiC (f-SiC) based innovative white light-emitting diodes (LED) because it can enhance the photoluminescence of the LEDs dramatically compared to as-grown SiC surfaces [1-5]. Nanostructures could be implemented on the SiC surface using e-beam lithography [4], nanosphere lithography [2], self-assembled Au nanoparticles [6] and Al thin film [7]. However, the large surface area also leads to the enhanced non-radiative recombination rate due to the surface defects and dangling bonds which are introduced during the nano-texturing fabrication [8]. In order to reduce the non-radiative recombination, Al_2O_3 deposited by atomic layer deposition (ALD) has been intensively studied to improve the surface performance in Si-based solar cells. ALD deposition provides excellent passivation for high aspect-ratio structures because of the conformal coverage and selective hydrogenation [9].

In this work, ALD deposited Al_2O_3 film was investigated as a passivation layer for the nano-textured f-SiC to improve the photoluminescence intensity. First, the morphology of nanostructured surface and its influence to photoluminescence enhancement were investigated. Then, the surface lifetime mapping of the samples was scanned by Micro Time 100 confocal microscope (PicoQuant GmbH, Berlin) [10].

The f-SiC samples with B and N ($\sim 10^{18} cm^{-3}$) dopants were grown by fast sublimation growth process (FSGP) [5]. A 20nm SiO_2 layer was deposited on as-grown f-SiC substrates by plasma enhanced chemical vapor deposition, followed by a 6nm Au film layer deposited by e-beam evaporation. The SiO_2 layer was applied to obtain a planar surface on as-grown samples. After treated by rapid thermal annealing (RTA) at 650°C for 3min, Au nanoparticles were self-assembled. Using the Au nanoparticles as mask, the nano-textured surface was formed on four samples (sample a, b, c and d) by utilizing reactive ion etching (RIE) for 5 min [6]. Finally, the SiO_2 layer was removed by rinsing samples in dilute HF (5%) solution for 3min.

For the Al_2O_3 film deposition, trimethylaluminium (TMA:$Al(CH_3)_3$) and H_2O gases were used as precursor materials in ALD reactor chamber. A layer of Al_2O_3 film was deposited on sample b, c and d with different thickness of 20nm, 50nm, 80nm respectively at 250°C. A post-deposition RTA treatment of sample b, c, and d was performed at 425°C for 30min in N_2 (10sccm) environment.

The cross-sectional SEM images of nano-textures without and with 20nm, 50nm, and 80nm Al_2O_3 are shown in Fig. 1. The 20nm thick Al_2O_3 film conformally covers the SiC nanocone structures, while the space between the nanostructures is gradually filled as the Al_2O_3 layer becomes thicker. For 80nm thick Al_2O_3 film, the space between nanostructures is almost completely filled.

From Fig. 2 (a), one can see that the transmittance is increased by 0.046, 0.049, 0.074 and 0.067 for nano-textured sample a, b, c and d, respectively, compared to the as-grown sample. The transmittance of Al_2O_3 passivated nano-textured f-SiC has not been significantly increased. This illustrates that the Al_2O_3 passivation layer (n=1.65) does not play an important role in the transmittance enhancement, especially in sample b.

After the deposition and annealing of the Al_2O_3 layer, the photoluminescence enhancement of sample b, c and d increased from 51.3% (sample a) to 77.2%, 61.4% and 57.4%, respectively, as shown in Fig. 2 (b). This large enhancement is mainly attributed to the surface passivation by the

Al_2O_3 thin film. The passivation layer suppressed the non-radiative recombination at the surface, which is mainly related to the presence of hydrogen from O-H bonds in Al_2O_3 layer. The H_2O was used as precursor material and introduced O-H to Al_2O_3 films [8]. During the thermal annealing process, O-H bonds obtained sufficient energy to brake and released H atoms. Then, H atoms diffused to the SiC/Al_2O_3 interface and saturated surface dangling bonds. Consequently, the luminescence efficiency was improved. In addition, the surface lifetime mapping of the samples measured by Micro Time 100 confocal microscope was consistent with room temperature PL results. The average lifetime of nano-textured sample a, b, c and d are 0.59ms, 0.86ms, 0.69ms, and 0.71ms, respectively. It can be seen that the lifetime of sample b, c and d has been increased due to the surface passivation by Al_2O_3 film.

In conclusion, our results show that the Al_2O_3 passivation layer could suppress the non-radiative recombination at the surface and enhance the photoluminescence intensity, especially for the sample covered by 20nm thick Al_2O_3 film.

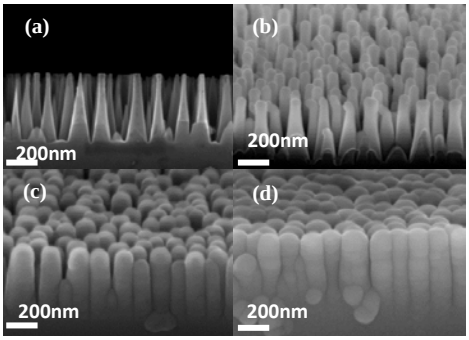

Fig. 1. (a) The SEM cross-sectional image of nano-textured sample. Tilted SEM view of f-SiC nano-textured surfaces deposited with (b) 20nm Al_2O_3, (c) 50nm Al_2O_3, (d) 80nm Al_2O_3 film.

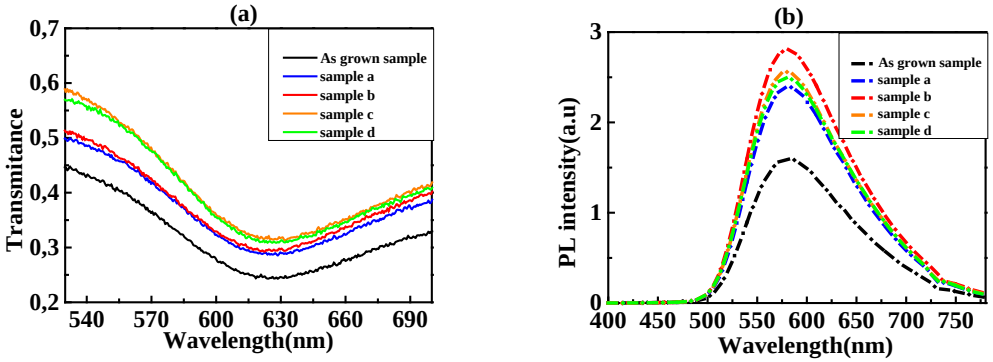

Fig. 2. (a) The optical transmittance curves measured in wavelength range of 520 to 700 nm and (b) photoluminescence spectra for the samples with different thickness of Al_2O_3 passivation films.

Acknowledgment

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References

[1] X. Zhu, et al., Applied Physics Letters 101 (2012) 241108.
[2] Y. Ou, et al., Scientific reports 4 (2014).
[3] Y. Ou, et al., Optics letters 37 (2012) 3816.
[4] Y. Ou, et al., Optics express 20 (2012) 7575.
[5] H. Ou, et al., European Physical Journal B: Condensed Matter Physics 87 (2014) 58.
[6] Y. Ou, et al., Optical Materials Express 3 (2013) 86.
[7] A. Argyraki, et al., Optical Materials Express 3 (2013) 1119.
[8] B. Dou, et al., Journal of Applied Physics 114 (2013) 174301.
[9] M. Otto, et al., Applied Physics Letters 100 (2012) 191603.
[10] V. Buschmann, et al., Journal of Applied Spectroscopy 80 (2013) 449.